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A Microfiche Storage and Retrieval System

J.R. Kenney

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ABSTRACT

Document storage on microfiche (reduced negative images on 4 in. × 6 in. film stock) has many advantages, and seems assured of continued widespread use for many years. By 1979, several automated microfiche systems were available, designed to serve the needs of businesses. However, none of the systems met the requirements established by a Canadian Government interdepartmental committee, formed in the 1970's to examine the requirements of an information storage and retrieval system to meet the needs of the several participating departments. Microfiche storage and retrieval would be a part of the system. In 1979, under contract, a technical and market study was submitted to the National Research Council of Canada, Ottawa, of an automated information storage and retrieval system, including both disc and microfiche storage, to meet the specifications of the interdepartmental committee. For the microfiche system, the microfiche would be held in small trays which in turn would sit on large horizontal shelves, stacked one above the other. Each shelf would hold up to 100 000 microfiche. On each level, trays would be delivered to a viewing station, the required microfiche withdrawn, and the required frame scanned by a high-resolution TV camera for transmission to monitors on viewing consoles. A contract to proceed with the construction of a prototype was not negotiated. However, many compelling arguments had been presented for the need for such a system, and a programme was initiated at NRC to proceed with a feasibility study. This paper describes the mechanism of a viewing station, and a small tray delivery system (up to 1000 microfiche) built along the lines of the submitted proposal.

RÉSUMÉ

L'archivage de documents sur microfiches (microcopies négatives sur film de 4 po × 6 po) a bien des avantages; il semble que l'usage de cette technique sera répandu pendant encore bien des années. Dès 1979, il existait plusieurs systèmes automatisés de microfiches destinés à répondre aux besoins des entreprises. Toutefois, aucun de ces systèmes ne satisfaisait aux exigences fixées par un comité interministériel constitué en 1970 par le gouvernement du Canada pour étudier les qualités requises d'un système de stockage et de restitution de documents répondant aux besoins des nombreux ministères participants. Dans le but de satisfaire à ces exigences, une étude des techniques et du marché portant sur un tel système automatisé, comprenant l'archivage sur disques et sur microfiches, a été présentée au Conseil national de recherches du Canada à Ottawa en 1979. Dans le cas du système de stockage sur microfiches, ces dernières seraient rangées dans de petits bacs empilés les uns sur les autres et déposés sur de grands rayons pouvant recevoir chacun 100 000 microfiches. A chaque étage, les bacs seraient acheminés vers un poste de visualisation où la microfiche voulue serait sélectionnée, puis, à l'aide d'une caméra de télévision à haute résolution, la microcopie d'intérêt serait repérée et retransmise sur l'écran d'une console. Aucun contrat n'a été négocié pour la construction d'un prototype. Cependant, beaucoup d'arguments soulignant la nécessité d'un système de ce genre ont été présentés; un programme a été mis en oeuvre au CNR en vue de réaliser une étude de faisabilité. Le présent article décrit le fonctionnement d'un poste de visualisation ainsi qu'un système de distribution des bacs (pouvant contenir 1000 microfiches) construits dans l'optique des propositions soumises.

A MICROFICHE STORAGE AND RETRIEVAL SYSTEM

J.R. Kenney

A MICROFICHE RETRIEVAL SYSTEM

The advantages of microfilms for information storage, compared to paper files, are well known, but bear repeating:

(1) a 98% saving in space requirements
(2) more rapid file accessibility
(3) lower cost of duplicating files
(4) greater file integrity

The photographically reduced pages may end up with the image of each page on a separate negative, with the images on a roll of film, or with many images in rows and columns on a piece of film about the size of an index card. In this format, over 100 pages can be stored on one negative called a "microfiche," commonly shortened to "fiche." The microfilms are normally read with a simple projection system, with some readers providing hard copy as well.

There are many different applications for microfilm storage, and each of the above formats has areas for which it is best suited. However, in the early 1960's the microfiche format came into widespread use for the dissemination of official reports by a number of American government agencies, and other institutions and businesses followed suit. As a result, many organizations have acquired vast files of microfiche. For example, the Canada Institute for Scientific and Technical Information has close to 1.5 million microfiche on file. As well as source documents, computer generated data are commonly stored on microfiche called COM (Computer Output Microfiche), for archival storage, or when replication and dissemination to many users is required.

Following this sudden growth in the use of microfilm in general, and microfiche in particular, there was also increased activity in the development of automated retrieval systems. The early ones were designed to service the active files of businesses and were not very sophisticated. Either their capacity was quite limited, or a two-step process was involved, with computer-aided retrieval of the required microform, followed by manual insertion into the viewer. However, over the last few decades, rapid advances in several technologies, namely computer, communications, and high resolution scanning systems, enabled designers to plan completely automated systems handling large information bases, accessed and viewed on terminals remote from a central storage file.

OPTICAL DISCS FOR MASS STORAGE

While new technologies are making sophisticated microfilm-retrieval systems feasible, there are other new technologies that may render such systems less attractive for many applications. The high-density optical disc is a case in point.

The role of optical video discs in computer systems and information storage and retrieval systems has not yet been established in the real world, but many predictions have been made based on the characteristics of the discs. With a capacity of one gigabyte (8×10^9 bits) per disc, the number of pages that can be stored is very large and depends upon the method of recording. Encoded text (one byte per character), although not suited for most figures, is the most compact, and 300 000 pages (3500 characters per page) can be recorded on a single disc. For graphics, the images would probably be digitized and, assuming a required resolution double that of standard television, 8000 pages of black and white images could be stored. If a grey scale were involved, this number would be reduced by a factor of at least four. This is 5 to 10 times the capacity of a magnetic disc, and the almost instantaneous random access feature of the magnetic disc is retained. Optical discs have greater permanency (5 to 10 years) than magnetic discs, although not nearly as great as that of properly processed microfilm (over 100 years). Currently available optical discs are not erasable, but erasable discs are under development, and will probably eventually be available.

Based on these characteristics, the most commonly expressed opinion is that optical discs will replace magnetic discs and microfilm for active files (providing the files are not of a kind that requires frequent updating), while microfilm storage will be used for inactive, archival files. However, in spite of the many obvious advantages of optical discs, there are experts in the field who believe that microfilm storage will have a significant role for many years, because of the cheaper cost per image. One such authority is T. Hendley of the National Reprographic Centre for Documentation, Hertford, England, who states, "For many applications, microfilm is at present the most cost-effective method of information storage and retrieval, and the use of automated retrieval systems will continue to grow over the next 5 to 10 years" (1).

PROPOSALS FOR MICROFICHE RETRIEVEL SYSTEMS

The National Research Council of Canada, Ottawa, has received two proposals for an automated microfiche retrieval system. The first was an unsolicited proposal received in 1974. This proposal was discussed by an

interdepartmental committee, but was not supported. However, the discussions led to a statement of requirements for a data storage and retrieval system to meet the needs of several governmental departments. In 1979, under an NRC-PILP (Program for Industry/Laboratory Projects) contract, a technical and market study of a system to meet these requirements was submitted jointly by Anstin Automation, Incorporated, and Promedic Manufacturing, Incorporated (2). The proposal involved computer-assisted retrieval from disc storage as well as from microfiche storage, the latter being the field of expertise of Anstin Automation.

The PILP Contract Proposal

The proposal submitted under the PILP contract (2) deals with both the software and hardware aspects of a computerized indexing system controlling a microfiche storage and retrieval mechanism. At present, we are concerned only with the latter, which is summarized in the proposal as follows:

> "The electro-mechanical fiche file retrieves stored microform on command from an operator at a remote console. The file is retrieved by a search-and-retrieval mechanism which carries the desired file to a viewing station where its contents are presented to a high resolution video camera. The image is transmitted to a high resolution video screen on the operator's remote control console. Through a video link, the operator can view any or all of the images contained in the file. Multiple cameras, search and retrieval mechanisms, and remote operating stations permit simultaneous access to the files by a number of viewers."

A noteworthy feature is the use of a high resolution video camera for read-out, rather than the usual optical projection system. The advantages of using a video system are listed below:

(1) The viewing monitors can be located remote from the storage centre, connected either by cables, or, for long distances, wide-band communications links.

(2) The users do not have physical access to the filmed information.

(3) With video switching, every monitor can have access to every fiche, even though a particular camera may have access only to a part of the files.

One disadvantage is that video cameras and monitors of the required resolution (1225 lines per picture height vs. 525 for commercial TV) are relatively expensive, $25 000 for the camera and $5 000 for the monitor.

The fiche would be stored in small trays. Three possible sizes are suggested, capable of holding 10, 20, or 40 fiche, depending upon file size requirements. With a separation of 0.050 in. between fiche, such trays would be ½, 1, and 2 in. in length. A minimum of additional fiche preparation would be required. The fiche would not be mounted in individual frames, but to facilitate pick-up, each fiche would have a stiffening bar of thin stainless steel folded and crimped on one edge. This is not mentioned in the submitted proposal, but was suggested by W. Anstin in a subsequent discussion.

The trays would be stored in rows on horizontal shelves. Up to six shelves could be stacked one above the other, with a net height of 6½ ft. The basic shelf unit would be 8 ft wide and 3 ft long so that it would go through an average door. Shelf units would be coupled together up to a maximum of 10 units (30 ft in length) depending upon system requirements. Six shelves of the maximum 8 ft × 30 ft size would store 600 000 fiche, or about 60 million pages. A simple calculation shows that in order to store this number of fiche on the proposed shelf-size, the fiche would have to be stored on end. This is not specifically mentioned in the proposal, but was confirmed in a subsequent discussion with W. Anstin.

On each level of the storage unit there would be a servo-controlled search and retrieval mechanism for the trays. The mechanism would run on rails the length of the unit (up to 30 ft) and across the width of the unit (8 ft). The maximum retrieval time for any tray would be 10 s.

The retrieval mechanism would deliver the required tray to a viewing station, of which there would be at least one per storage level, up to a maximum of four per level. Each viewing station would have a mechanism for extracting a designated fiche from the tray and exposing an individual frame to the video camera. The operator at the remote console would be able to "browse" through the complete file or to select a specific page from the fiche in that tray. If hard copy is required, units can be added to the remote terminal to provide a copy of the image displayed on the video monitor in 4 s. After viewing, the mechanism would replace the fiche in the tray and return the tray to its proper location on the shelf.

The address to designate the required fiche and frame would be generated from a computerized index by keyboard request at a viewing console. The resulting address would contain a minimum of six parameters; shelf number, the X and Y coordinates of the tray on the shelf, the fiche number in the tray, and the row and column of the required frame.

The Anstin proposal also deals with the problem of infiling, purging, and microfiche duplication, all done in an "Infile, Purge and Reproduction

Bay." This unit would be situated at one end of the storage bay, opposite the viewing stations. New microfiche would be inserted into a special in-file tray, at one level, and transferred by a pick-up and insert mechanism into the required tray. Since there would only be one infile tray to serve all shelves, there would have to be an "elevator" to bring fiche up and down from the input level. Similarly, fiche from all levels would be brought to a single level for duplicating on a diazo duplicator. This is beyond the scope of the present investigation, and only a simple manual infile and purge system will be described.

Competing Systems

At the time of the proposal there was no known system with all of the characteristics of that proposed by Anstin Automation, Inc. The closest competitor was a system described in the Journal of Micrographics, May/June 1979, by D. Fain and G. Gruener of Teknekron, Inc., Berkley, California (3). The system is called ARMS, an acronym for Automated Records Management System. The microfiche are held in carousels, each holding up to 900 000 images and requiring 4 ft^3 of space. More carousels are added to expand the system.

To quote from the article, "The computer index (accessed through the video terminal) allows the researcher to home in quickly on the necessary materials ... ARMS selects the particular fiche and page of interest and presents it to a CCD (charge coupled device) camera, contained within each carousel. The CCD camera then digitizes the microimage and sends the information to a computer disc. Once on the disc, the image is relayed to and displayed at any of the high resolution terminals in the system ... With appropriate wide-band links, these terminals can be located at great distances from each other." Access time is about 5 s.

Carousels are more compact than a storage shelf arrangement (4 ft^3 for a million frames vs. 24 ft^3), but infiling, purging, and temporary removal of a fiche for duplication would probably not be as convenient as with a system employing small storage trays.

In the publication "Automated Computer Assisted Retrieval of Microforms: A Guide and Directory", 2nd edition, 1983 (1), six microfiche retrieval systems (including ARMS) are listed as being "videomicrographic," i.e., the image is electronically scanned, usually with a CCD array scanner. Most, if not all, of these systems are extensions of systems designed for projection viewing, and most require a machine-readable code on the micro-fiche. Only one of these system has duplicate microfiche listed as an output. This is the Access 2010, a large capacity system (252 000 fiche) which requires that each fiche be coded on the bottom with a notch pattern (4).

Videomicrographic systems are described in the Guide and Directory (loc. cit.) as "expensive systems ranging in price from one hundred thousand to several million pounds, and aimed at large organizations with extremely sophisticated retrieval requirements ... The majority of videomicrographic systems on the market to-day are customized to suit individual companies specific requirements, and in many cases the companies supplying the systems can best be regarded as systems companies, rather than hardware suppliers."

Anstin Cost Estimate

For a prototype model, a scaled down version was proposed by Anstin Automation, with two cameras and two monitors. The two cameras would be mounted on one 8 ft × 3 ft section of shelf, holding 10 000 microfiche. The shelf would be filled with injection-molded plastic trays, 1000 being required for the small 10 fiche size. A hard copy unit and a film processing unit were included in the estimates, but magnetic disc buffering for temporary image storage was not included. Anstin Automation estimated that the above hardware, together with the required computers, software, and control electronics, could be provided for $530 000 in 1979 Canadian dollars.

Because of the high risks involved, an agreement was not signed with Anstin Automation to proceed with this phase of the proposal. However, because many compelling arguments had been presented for the need of such a system, a programme was initiated at NRC to proceed with a feasibility study, to identify the problem areas.

PRELIMINARY CONSIDERATIONS FOR A VIEWING STATION

Starting with the proposal that the fiche be contained in small trays, holding 10, 20, or 40 closely spaced fiche, one of the remaining problems not detailed in the proposal is to extract a designated fiche from the tray and to sandwich it between two pieces of glass or plastic. The enclosed fiche must then be moved in X and Y in the field of the viewing system. The most obvious approach seemed to be to have the window pieces spring-loaded so that they would close automatically upon the fiche unless acted upon by some opening mechanism.

For loading, the window pieces would sit just above the tray slightly spread apart, and the required fiche would be grasped and drawn up between the pieces of plexiglass. The window pieces would close when the fiche is drawn up completely within the window. The vertical motion would continue, now lifting the window pieces as well, until the required row of the fiche is in the field of the viewer. A controlled horizontal motion would also move the enclosed fiche so that the required column would be viewed. Inserting the fiche back into the tray would be a reverse procedure, with the

added feature that guides would have to be provided to direct the fiche into its proper slot.

Starting with the above conception, a working model of a viewing station was constructed, together with a tray delivery mechanism. A detailed description follows, and some of the reasons for certain design decisions are given.

Microfiche Characteristics

To begin with, samples of several dozen microfiche were obtained from different sources, and several things were noted:

(1) Fiche from different sources are very close in dimensions (105 mm × 148 mm), but there are different formats. Of the fiche obtained, some have a 6 row by 12 column format and some have an 8 row by 14 column format. This difference could be accommodated by the X and Y control circuits.

(2) The frames are not uniformly positioned on the fiche. Sometimes they are shifted towards one edge, or towards the top. However, on all of the sample fiche, there was at best 1/8 in. of free space at the bottom, so that any gripping mechanism could stay in place during viewing if it covered up no more than this.

(3) Of the original fiche samples, all had square corners. With samples obtained since then, some have one of the top corners either clipped or rounded (1/4 in. radius approx.). Had this been realized, it will be seen later that it would have affected the tray design.

(4) Fiche may vary in thickness from 0.004 to 0.008 in.

The Trays

The experimental trays are made of aluminum, and consist of vertical side pieces screwed to a bottom plate, as shown in Fig. 1. There are 10 slots in each side piece, the slots being 0.025 in. wide with 0.060 in. centre-to-centre spacing.

For the first experiments, thin stainless steel stiffening bars were folded and crimped across the bottom of each fiche. The bottom was chosen because, as previously noted, all the sample fiche have at least 1/8 in. of free space at the bottom, but not always at the top. The fiche are inserted with the bars uppermost, and therefore the fiche are upside-down in the trays.

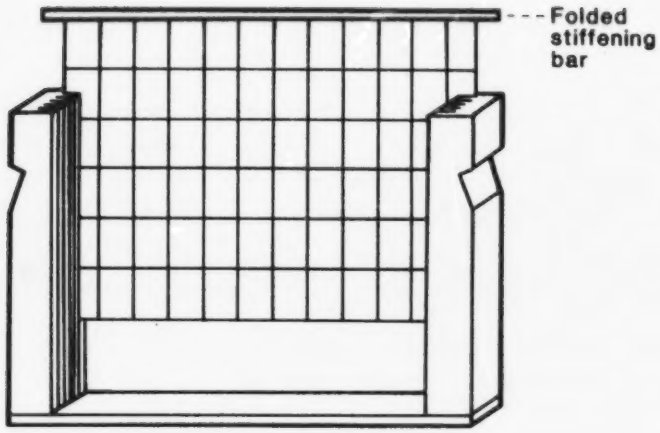

Figure 1. Tray for use with microfiche with stiffening bars across the tops of the microfiche.

Although stiffening bars are no longer used, the procedure is mentioned because it determined the minimum fiche spacing in the trays. With a folded bar thickness of 0.040 in., a fiche spacing of 0.060 in. was considered to be a reasonable minimum. This spacing remains, although without the bars, it could probably be reduced to 0.050 in. as originally proposed.

The stiffening bars were eliminated for the following reasons:

(1) It is best not to have to do any fiche preparation.

(2) Some fiche that had been thus prepared developed wrinkles at the bar, presumably due to differential expansion of the film and steel. Depending upon the depth of field of the viewing system, this could cause problems.

(3) If one intends to have a microfiche duplicator as part of the system, the stiffening bars would not be tolerable for any diazo duplication machine examined to date.

However, it turns out that what one saves in fiche preparation, one expends in tray complexity. With bars across the uppermost edges, the fiche are kept in their own compartments across the whole width of the tray. This is necessary when re-inserting an adjacent fiche. With no bars on the fiche, separation pieces must be added at the top of the trays (Fig. 2). These pieces should be thin, yet rigid, and for this reason 0.015 in. spring steel is used.

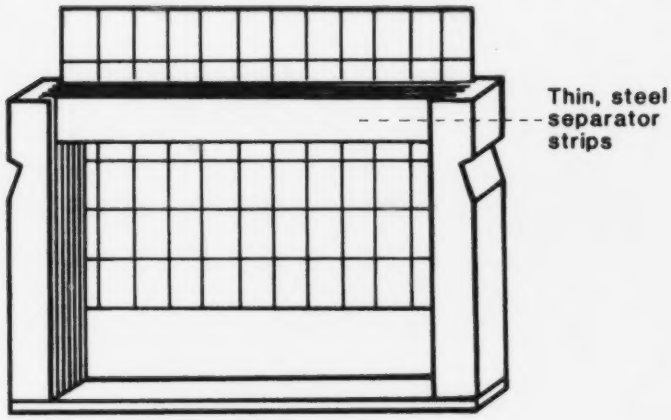

Figure 2. Tray for unadulterated microfiche.
Note separator strips at top of tray.

The Push-rods

Since the fiche are closely spaced, the required fiche must be pushed up a bit before it can be grasped and pulled out of the tray. This is done with small push rods that move through holes in the bottom of the tray, and into the vertical slots on each edge of the tray.

The push-rods should be larger in diameter than the slot width, so that the fiche will not jam between the rod and the wall of the slot. With the hole tolerances necessary and the tray dimensions used (0.060 in. centre-to-centre spacing, 0.025 in. slot width), it would be difficult to have push-rods of the required diameter if only a single pair of push-rods were used. However, the difficulty can be overcome with two pairs of push-rods and staggered holes in the tray bottoms, as shown in Figs. 3 and 4. One pair of push-rods is used for odd-numbered fiche locations, and the other for the even-numbered ones. The push-rods are operated by rotary solenoids, converted to a linear travel of 3/8 in. With allowances for vertical clearance, and for penetrating the tray bottom, the fiche are pushed up by 3/16 in.

The outer pair of push-rods operates very close to the edges of the fiche, i.e., within 1/8 in., because fiche with clipped or rounded corners were not originally considered. Consequently, with such fiche, the outer push-rods engage the clipped or rounded portion. There is enough extra travel in the push-rods to accommodate this, and there does not appear to be any problem with these fiche. However, if a re-design were undertaken, it would be better to have the push rods operate further from the edges of the fiche.

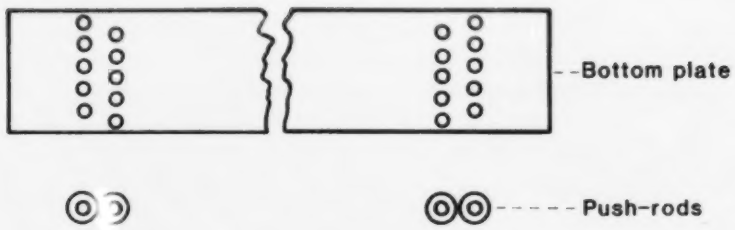

Figure 3. Bottom plate of tray and push-rods, top view.

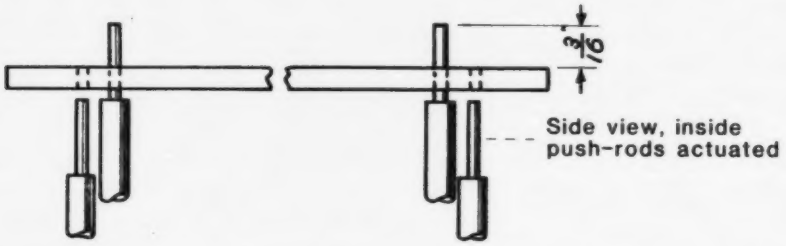

Figure 4. Bottom plate of tray and push-rods, side view.

Because of the staggered holes for the push-rods, the trays are not symmetrical, i.e., there is a front and back. The trays should therefore be keyed in some way so that they cannot be inserted incorrectly.

Grippers

Assuming the tray is positioned with the required fiche over the push-rods, the fiche can be pushed up so that it can be grasped with some sort of gripper mechanism. The grippers are solenoid operated and designed so that the power-off condition is the closed or gripping condition, with spring tension providing the gripping force. Power is applied only to open the grippers. With stiffening bars on the fiche, the grippers used the protruding ends of the bars (Fig. 1), and no part of the gripper had to pass between the window pieces.

For operation without the bars, grippers were designed to grasp the upper corners of the fiche, covering not more than 1/8 in. along the edge of the fiche. It was desirable to minimize also the thickness of the grippers, because they have to pass between the separated window pieces. One of the grippers is shown in Fig. 5, with some pertinent dimensions. The moveable parts are quite small in cross-section (1/16 in. × 1/8 in. with a beveled edge). For strength, these pieces are made of heat-treatable steel, ground to final dimensions after heat-treatment.

The grippers ride up and down two vertical steel rods (3/8 in. square, 8 in. apart) on linear bearings. The gripper mechanisms are not fastened

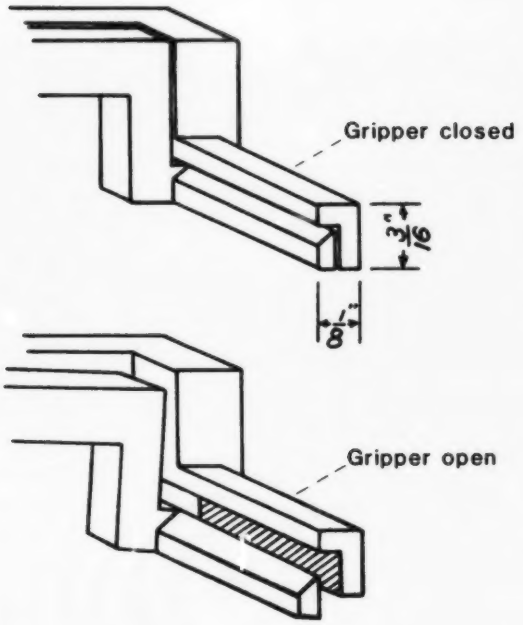

Figure 5. One of the two grippers, shown closed at the top and open at the bottom.

rigidly to the linear bearings, but are mounted on short horizontal shafts, permitting the grippers to rotate upwards if resistance is met when re-inserting a fiche. Contacts are broken if rotation occurs, stopping the downward motion. The motive power for the vertical motion is a stepping motor, operating through a chain and sprocket drive.

To ease the load on the vertical stepping motor, the system is counter-balanced. Sometimes the grippers carry the window and sometimes not, and so the counterbalances are designed to counteract the grippers and one-half the weight of the window. In this way, loaded or unloaded, the imbalance in the system is always one-half the weight of the window, a 10 oz. imbalance.

The Window

The window pieces are made of 3/16 in. plexiglass and are spring loaded so that they automatically close on the fiche. There are four "C" brackets supporting the springs as shown in Fig. 6. The lower brackets are right at the bottom of the window pieces and have low vertical profiles so that there is no interference with the gripper mechanisms at the lower end of their travel. The lower brackets are also shown to extend sideways almost 2 in. beyond the edges of the window. This is to accommodate guides for re-insertion, which will be discussed later.

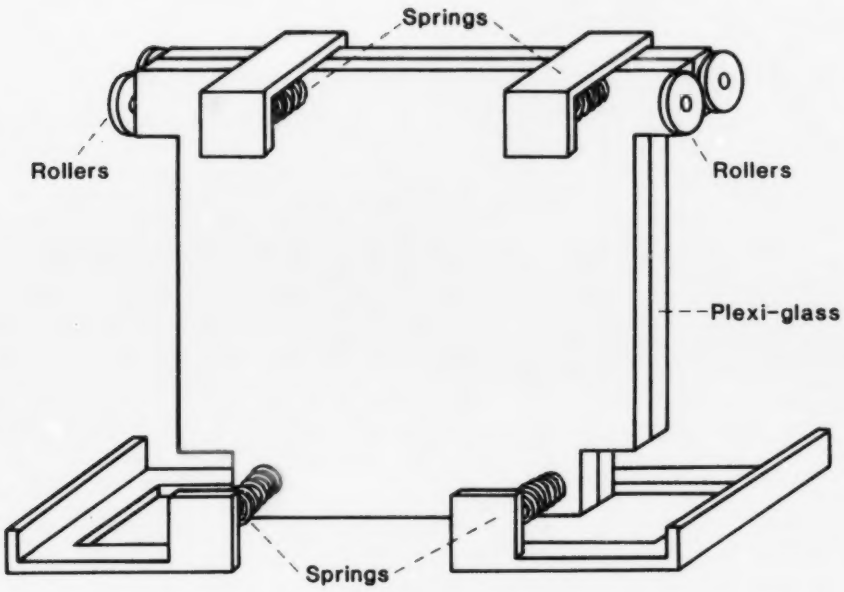

Figure 6. Window pieces.

To pull a fiche up between the window pieces, the window assembly sits on two flat rails, one on each side of the push-rods, and at a height just sufficient for a tray to pass beneath. Furthermore, the window pieces must be in their open, or spread apart condition. Spreading of about 1/4 in. is accomplished by four rotating arms, wedge-shaped at the ends, which act between rollers to separate the window pieces at each corner. On the upper corners the rollers are fastened to the window pieces, while for the lower corners, the rollers are fastened to the rails on which the window sits. On each of the rails there are two projections (3/8 in. high) which engage the window when it is sitting on the rails. As a result, separating the rails in turn separates the window pieces at the bottom.

The rotating arms are coupled by a chain drive to a small dc motor. When the arms are not being used, they are rotated 180° so that they do not interfere with the window assembly when it is moved horizontally and vertically to expose individual frames to the video camera. The mechanics of this drive are discussed in Appendix A, as well as the possibility of replacing the motor with rotary solenoids.

Tray Carriage

Before considering a fiche pick-up sequence, the tray carriage should be described. This is a horizontal carriage, with a motion perpendicular to the plane of the fiche. At one extreme of its travel, it protrudes from the device so that trays can be loaded into, or unloaded from, an open box on

the end of the carriage. At the other extreme of its travel, it positions the tray so that the requested fiche is directly over the push-rods, and under the window. This positioning must be done with considerable accuracy, since the holes in the tray for the push-rods only allow for ±0.010 in. error in tray location. Using a stepping motor, the required accuracy can be obtained either with a small travel per step, or by designing the drive so that a small number of steps drives the carriage precisely the distance between fiche (0.060 in.). The latter method also makes it easier to obtain a high carriage speed, and so it is the method used, with four steps required per fiche spacing.

To locate the required fiche, there is a four-digit, binary-coded commutator plate fastened to the carriage. With four stationary probes making contact with the commutator plate, the carriage is driven to the vicinity of the requested fiche, and the precise location is determined by the phasing of the drives to the four windings of the stepping motor.

The total travel of this carriage is 6 in., and it should be noted that it is a cantilever arrangement (Fig. 7) so that it can protrude from the device for tray loading and unloading. However, the rails do not extend as

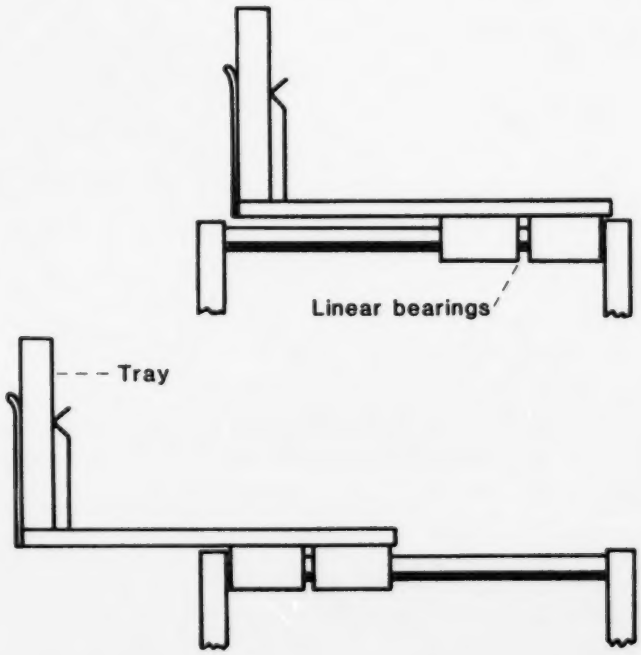

Figure 7. Tray carriage. Above, retracted in viewing position. Below, extended in tray load/unload position.

far forward, so that with the carriage in, there is no interference with the vertical supports when they are moved horizontally right or left to locate the required frame on a fiche.

Fiche Pick-up Sequence

Assume the window is sitting in the load position, that is, on the rails and wedged open. The grippers will be in their rest position which is about 1/8 in. up from the top of the tray. Assume also that the tray carriage is extended out in its load/unload position, and that a tray has been inserted. The following sequence of events for a fiche pick-up is controlled by integrated circuit boards, with transistor amplifiers to drive the solenoids and motors involved:

(1) tray in and stop with requested fiche over push-rods;
(2) open grippers;
(3) push up fiche;
(4) grippers down to top of tray;
(5) close grippers;
(6) release push-rods;
(7) up motion until grippers lift window off rails (at this point the fiche is in place between the window pieces);
(8) rotate arms, allowing window to close on fiche;
(9) continue up motion until required row is exposed to viewer.

This last function in turn has several steps. After window lift-off and closure, up motion continues for about 1 in., determined by a step count. This is the lowest level at which the window is clear of obstruction (guides for re-insertion) and can be moved right and left. It is, therefore, the lowest level at which the fiche can be viewed, and the camera is adjusted to view the uppermost row of the fiche in this position. A row counter is set to correspond to the number of this row. For fiche with 6 rows, and inverted in the tray, the upper row number would be 5, since it is simpler, but not necessary to number rows, columns, fiche, etc., from zero rather than from one. If row 5 were the requested row, vertical motion would stop. If not, vertical motion would continue, counting the required number of steps for each row, until the required row is reached.

Right-Left Carriage

The window-pieces and the enclosed fiche must also be moved to the right or left by a horizontal carriage to view the requested column. The required travel is the width of the fiche, or a little less than 6 in. This carriage must carry the vertical motion mechanism, which consists mainly of the two vertical rails on which the grippers ride up and down, each driven by a

chain and sprocket arrangement. The vertical motion stepping motor is mounted on the base, rather than on the carriage, and the shaft motion is transferred to the vertical chain drive by a pinion running the width of the device.

Also on the right-left carriage there is a simple photocell arrangement, which enables the carriage to be precisely re-centred, i.e., to the same step of the stepping motor, since re-centering is necessary before a fiche can be returned to its tray. This carriage is the foremost item in Fig. 8, a front view of the viewing station, and its relationship to the camera and other parts of the unit can be seen in Fig. 9.

To find the required column after a fiche pick-up, we should note that we are sitting initially at the centre of the fiche (symmetrical mechanical design seemed simplest). With an even number of columns, 12 for example, we are sitting at column 5 1/2, again numbering from zero.

If X = column address, and n = number of horizontal steps per column, then the initial column search logic is as follows:

If $X < 5$, go left n/2 steps (half a frame) and set column counter to 5.

If $X = 5$, end of column search.

If $X < 5$, continue left. For every n steps **subtract** one from counter until required column is reached.

If $X > 6$, go right n/2 steps (half a frame) and set column counter to 6.

If $X = 6$, end of column search.

If $X > 6$, continue right. For every n steps **add** one to counter until required column is reached.

Frame Changing

With a microfiche in the viewing position, there are several ways in which one can change the frame being viewed with the present control circuits. A new address can be given with a change in row and/or column address. Logic circuits compare the new address to the old, to determine what action is required, i.e., same fiche, new fiche from the same tray, or new fiche from a new tray. If only the row and/or column address is changed, the up-down drive and the right-left drive move the fiche to the required frame by counting steps of the stepping motors.

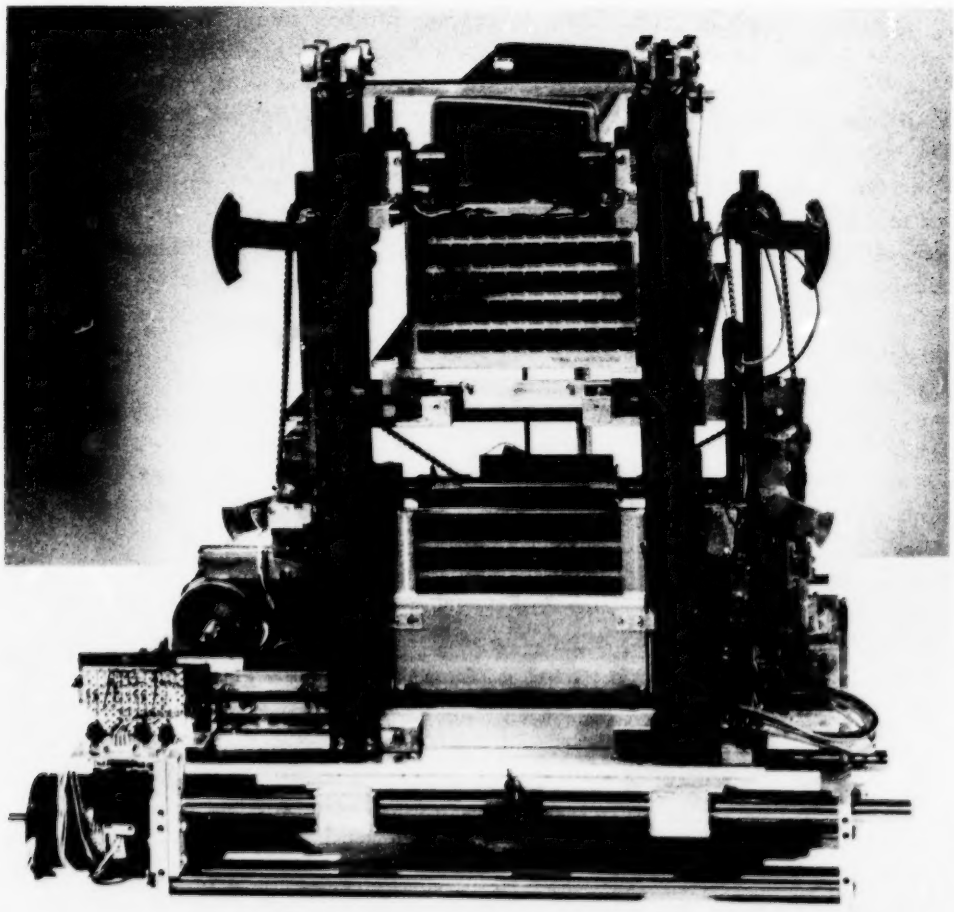

Figure 8. Front view of the viewing station. For clarity, the illumination system has been removed, as well as the light-dispersive material on the near window piece.

On the control panel there is also provision for advancing or retarding a frame at a time. If the advance-a-frame button is pushed while viewing the extreme right-hand column, the circuitry drives the carriage back to the zero column, and advances to the next row. Similarly, if the back-a-frame button is pushed while viewing the zero column, the circuitry drives the carriage to the extreme right-hand column, and backs up one row. This could be extended further, so that if the last frame of a fiche is being viewed when the advance button is pushed, a fiche change would be made and the first frame on the next fiche would be presented. On the prototype, however, if one tries to back up or advance too far, no fiche movement occurs,

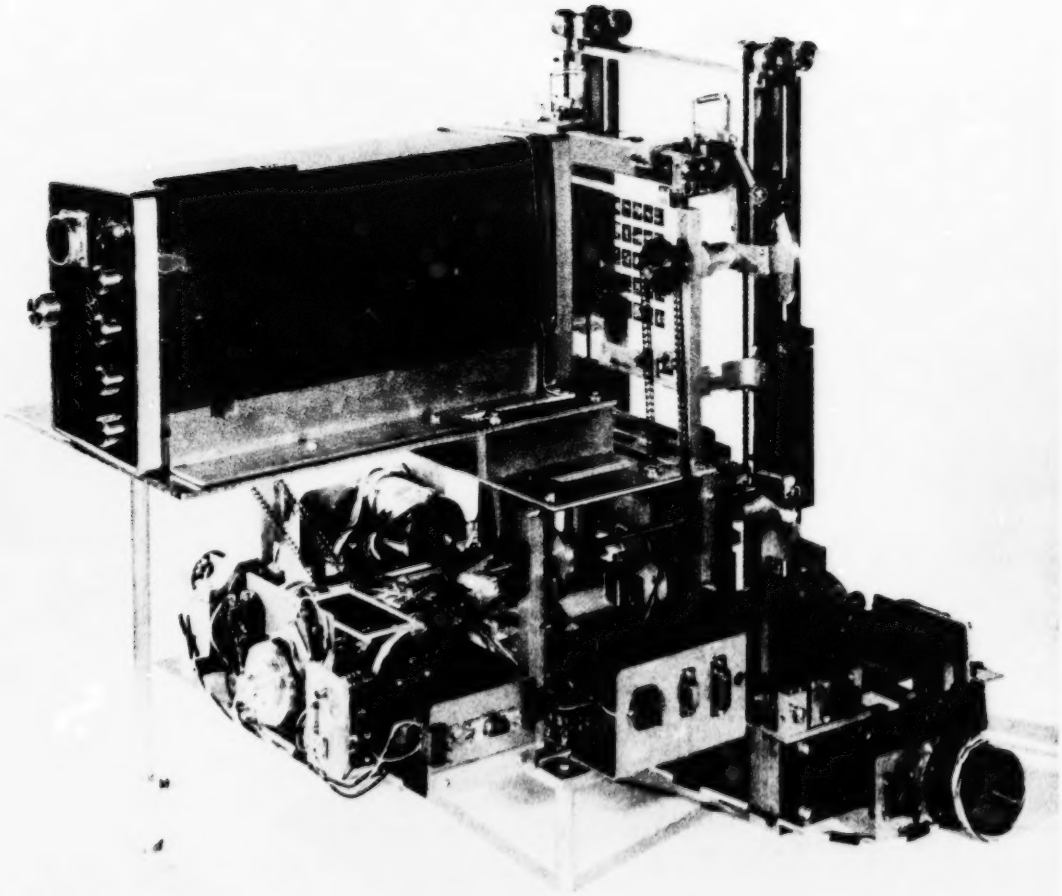

Figure 9. View from the side and rear of the viewing unit.

and an intermittent tone is sounded for a few seconds. (This tone is also sounded if an address is requested which is not locatable, e.g., the row or column number is too large.)

For a given format, the frames are consistently located with respect to each other on a fiche, but the area containing the frames is not consistently located. For this reason, two lever switches are provided on the control panel, an up-down and a right-left control for centering a frame. This adjustment should only be required once per fiche.

The Optical System

The camera location and the illumination arrangement is shown in Fig. 10. Several points should be noted:

(1) The camera must be very close to the microfiche and requires a close-up lens.

(2) The light from the lamp (12 W) passes through a condensing lens (focal length 4 in.) to provide uniform illumination over the viewed area. The lens is positioned 4 in. from the fiche so that there is no interference with the uprights on the right-left carriage.

(3) The window piece nearer to the light source is covered with a piece of thin, light-dispersive plastic.

(4) The light from the lamp is reflected by a 45° mirror as shown in Fig. 10, so that the lamp assembly does not interfere with the tray delivery mechanism.

Re-insertion Guides

To return a fiche to its tray, it must be guided rather precisely into its slot. To guide the edges of the fiche, there are small edge guides which rotate into place at the appropriate times using rotory solenoids (Fig. 11). In the down position, these guides make physical contact with

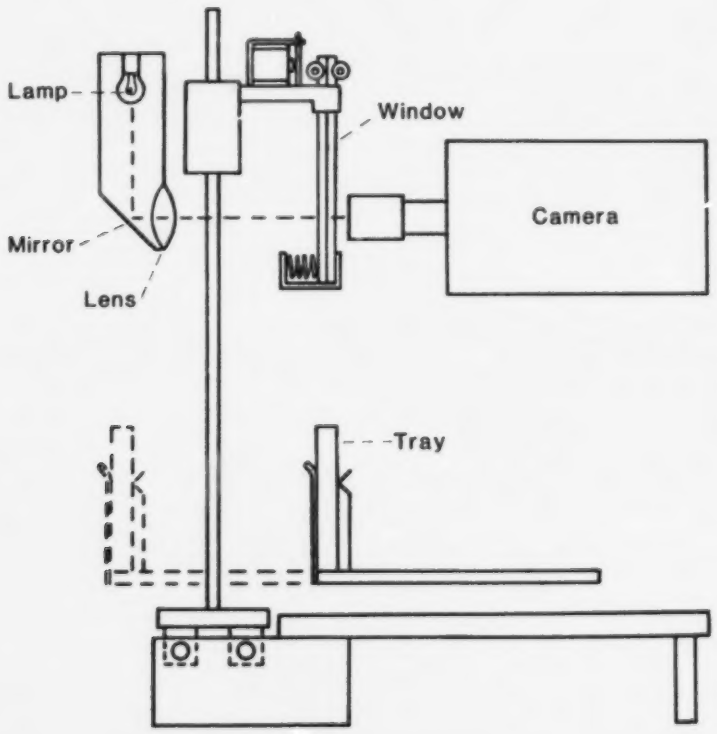

Figure 10. The camera and illumination system.

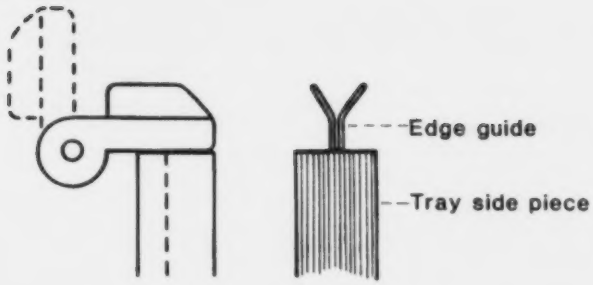

Figure 11. One of two rotating edge guides.

the top of the tray, and are guided by grooves in the top of the tray to line up precisely with the slots in the tray.

The centre portion of the fiche must also be guided for re-insertion so that the fiche will not bow out and catch on the separator strips. Less precise guidance can be used for the centre portion than for the edges, and it is provided by the window pieces. An explanation follows.

When the window assembly is lowered onto the rails (the first step in a re-insertion procedure), it is engaged by projections on the rails. With no action from the spreading mechanism, these projections are designed to spread the window pieces very slightly at the bottom, just enough to pass a fiche. For the second step in re-insertion, the window pieces are spread only at the top by the rotating wedges, permitting the grippers to lower sufficiently for the fiche to the guided for 1/4 in. or so into its slot by the edge guides and the narrow opening at the bottom of the window pieces (Fig. 12a). After the fiche has been properly started into its slot, the windows are spread fully at the bottom as well, and the edge guides are released (Fig. 12b), permitting the grippers to be driven to the bottom of their travel, i.e., to the top of the tray, at which point the fiche is released.

Fiche Return Sequence

The fiche return sequence can now be described:

(1) Centre right-left carriage.

(2) Down motion until window sits on rails.

(3) Rotate wedges to open top of window. Rotate edge guides into position.

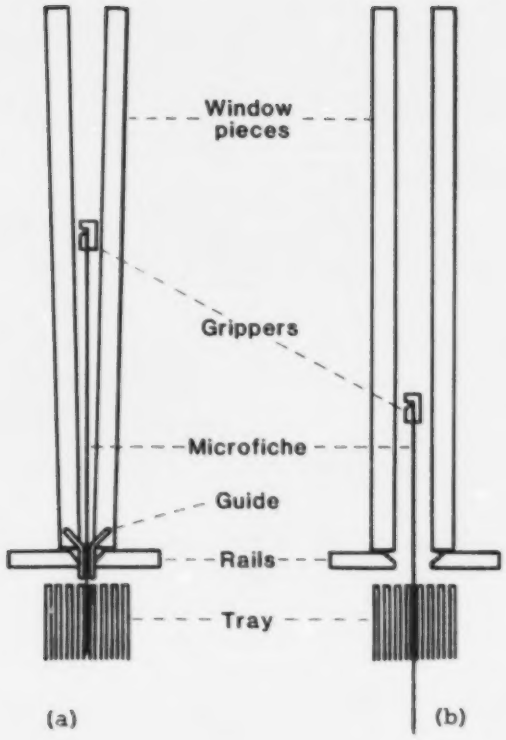

Figure 12. Microfiche re-insertion, edge view. (a) Top of window spread fully, bottom spread slightly. (b) Both top and bottom spread fully.

(4) Resume down motion until fiche is partially inserted (determined by a step count from window-on-rails condition).

(5) Rotate wedges to open bottom of window as well. Release edge guides.

(6) Resume down motion until grippers hit top of tray.

(7) Open grippers.

(8) Small up motion.

(9) Close grippers.

(10) Down motion to push fiche completely into tray.

(11) Small up motion.

Following this insertion procedure, the tray carriage would be operated to change fiche or to change trays, depending upon the requirement as determined from the new address.

Time Required

The time required from the tray load position to the farthest frame on a fiche is 6 s. The time required for a fiche change (same tray) is 10 s in the worst case. These times could be decreased in two ways without increasing the size of the stepping motors. Firstly, the horizontal and vertical searches could take place simultaneously instead of sequentially, after the vertical motion has reached the minimum level required for horizontal motion. Secondly, a more sophisticated system could be used to drive the stepping motors. The simplest electrical drive is being used at present, with voltage of one polarity applied to the windings (uni-polar drive). Only two of the four windings are energized at any one time. With bi-polar drive, all four windings are energized at all times, and the torque is increased by 25%, with the same power dissipation in the motor. A further increase in torque and stepping rate can be obtained with a bi-polar chopper drive, in which the winding currents are limited by a chopper regulator. With an increase in stepping rate, however, it would probably be necessary to modulate the stepping rate, to provide periods of acceleration and deceleration. It will be shown later that this was found necessary for the tray delivery system.

Handling Different Formats

In the discussion so far, a 6 row × 12 column format has been assumed. There are four parameters used by the logic circuits that would require changing for a different format (Table 1).

Table 1

Parameter	Format	
	6 × 12	8 × 14
Maximum row count	5	7
Maximum column count	11	13
Vertical steps per frame	71	55
Horizontal steps per frame	64	50

The parameters required for initializing the column counter were shown to be 5 and 6 for the first format, and they would be 6 and 7 for the second. These parameters are not entered as such, but are derived from the maximum column count.

The number of steps required per frame were determined approximately by measuring the height and width of the frames on the fiche, and dividing by the travel per step, namely 0.009 in. in the vertical direction and 0.007 in. in the horizontal direction. These calculated step numbers are entered into binary switches provided for this purpose, and "fine-tuned" experimentally to determine the optimum number of steps, both horizontally and vertically, for the two formats.

There is one other parameter that it may be advantageous to change for different formats, and that is the vertical initializing position. With the two formats being used, there is a small vertical difference between the centres of the uppermost rows (about eight vertical steps). This can easily be taken care of by the centering controls after the frame has been located. However, on the prototype a circuit has been added to adjust for this automatically when the "format change" function is actuated.

Binary switches are provided to enter two sets of parameters, and provision could be made to handle more than this, if necessary. At present, a two-position switch is used to select the required set of parameters. In actual practice, if fiche of different formats were intermixed, another digit could be added to the address to indicate the format and to change automatically to the required parameters.

Physical Parameters of the Viewing Station

The outside dimensions of the unit are 21 in. wide, 18 in. deep, and 20 in. high, and the weight is 57 lb without the camera. The width is such that four units could be placed across an 8 ft shelf as originally proposed. However, the height of 20 in. (not including a supporting structure) is greater than the height required for a shelf, i.e., 12 in. to 16 in. If this latter dimension is the governing factor in order to obtain the greatest storage density per unit volume, then the viewing stations would have to be staggered vertically, as shown in Fig. 13, limiting the number of cameras to two per shelf.

Electronics

The control electronics consists of integrated circuit boards followed by transistor amplifiers to drive the solenoids and motors. Approximately 110 integrated circuits are used for the control of the viewing station. Some of the typical logic functions required are illustrated in Fig. 14, which shows the required steps for the advance-a-frame and back-a-frame circuits. With microprocessor control, the number of integrated circuits could probably be reduced to less than 20, with the major circuitry being the transistor amplifiers.

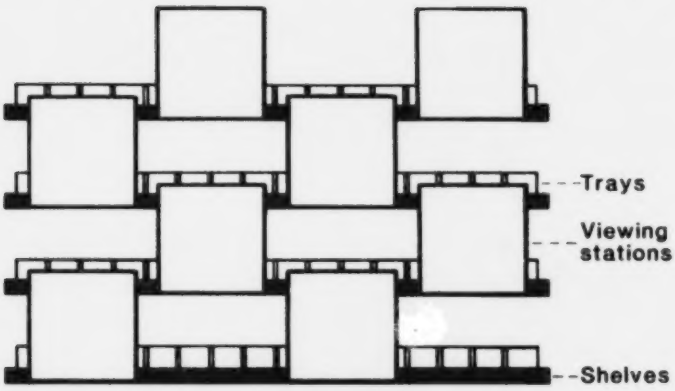

Figure 13. Possible arrangement of viewing stations to service the shelves. Drawn to scale, with shelves 8 ft wide and 1 ft separation.

TRAY STORAGE AND RETRIEVAL, PRELIMINARY CONSIDERATIONS

For tray storage and retrieval, modular shelves were proposed, one above the other up to a total of six, and with maximum horizontal dimensions of 8 ft × 30 ft. Minimum shelf size, i.e. the size of one module, was to be 8 ft × 3 ft.

For an experimental model, a more modest shelf unit was considered, possibly holding 100 or so trays. The tray retrieval system would be essentially a miniature travelling crane. In the design of the system, the following objectives would be kept in mind.

(1) The concept of modularity. For any members running the length of the unit (rails, pinions, commutators) it should be possible to joint shorter lengths together to obtain the required length.

(2) The design should not preclude the use of a third lengthwise rail to support the centre of the travelling cross-rails. This might be needed if an 8 ft width were used.

(3) The following parameters should be kept to a minimum:

(a) the height
(b) the weight of the travelling mechanism
(c) the number of commutator rails running the length and width of the unit
(d) the separation between trays

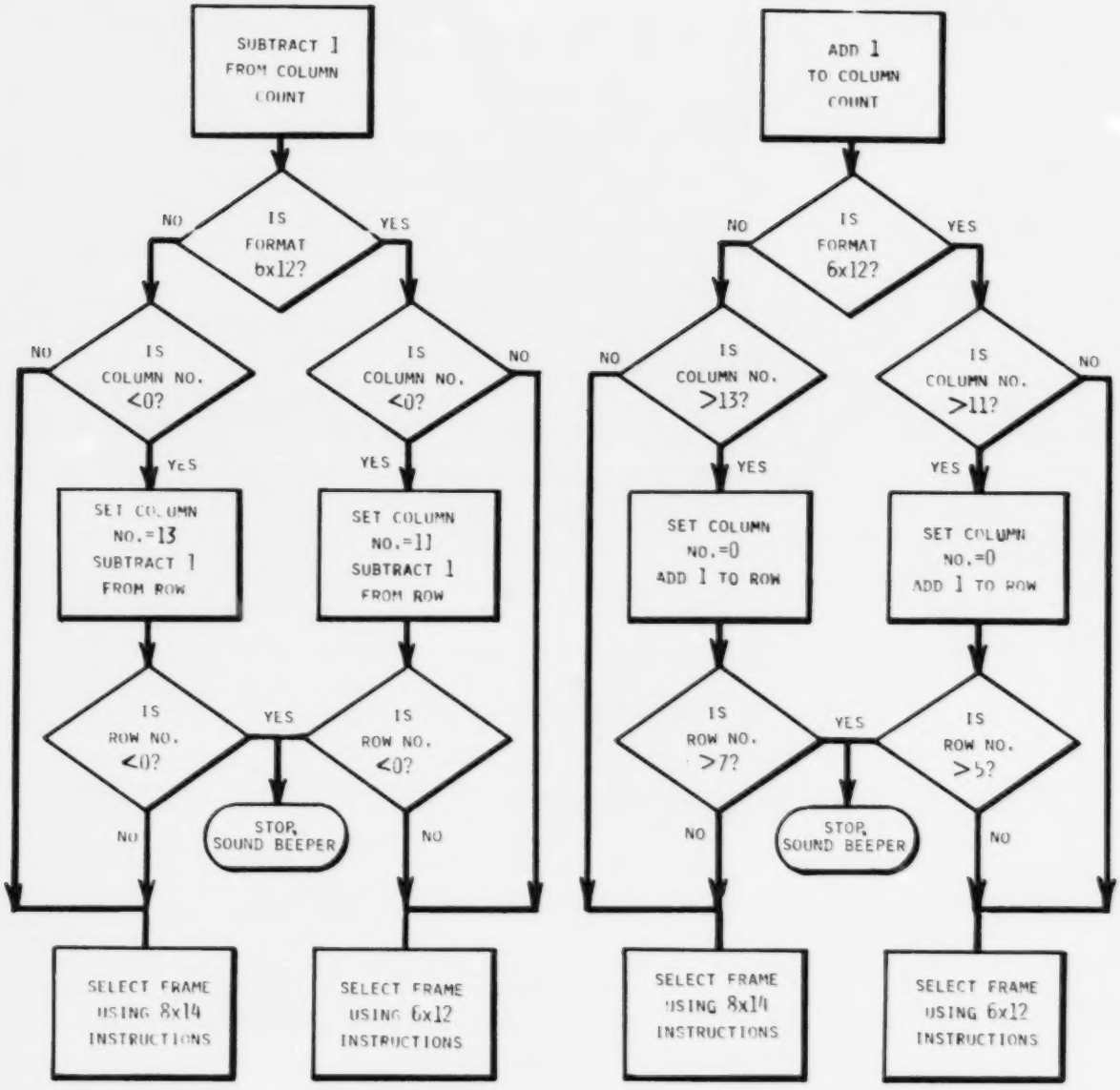

Figure 14. Steps involved in advancing or retarding one frame, for the two formats used.

The shelf is approximately 3 ft × 3.5 ft with a useful tray-storage area sufficient for 100 trays, 4 across and 25 deep. Tray separator strips, running lengthwise and crosswise, are fastened to the top surface of the shelf to form shallow rectangular compartments, 6 3/8 in. × 11/16 in., to hold the upright trays. The widths of the separator strips are determined by the clearance between trays needed for the pick-up mechanism. As a

result, the lengthwise separator strips are 1/2 in. wide, and the crosswise strips are 1/4 in. wide.

Rails and Commutators

The lengthwise rails on each side of the shelf are supported 5 in. above the surface of the shelf (Fig. 15). Commutator strips, four on each side, are fastened to the rail supports for carrying control and power signals to the pick-up mechanism.

The travelling rails (3 in. apart) span the width of the unit, and are fastened to two-wheeled carriages that run along the side rails. The 3 in. separator strips for the travelling rails are made of bakelite, so that commutator strips can be fastened directly to them. There are six commutator strips, again for control and power signals related to the pick-up mechanism.

The Pick-up Mechanism

A four-wheeled carriage riding on the cross-rails carries the pick-up mechanism. This is essentially an inverted "U" shaped structure, which travels up and down vertical rods (Fig. 16), driven through a 5 in. travel by a chain and sprocket drive from a small dc motor. The vertical end

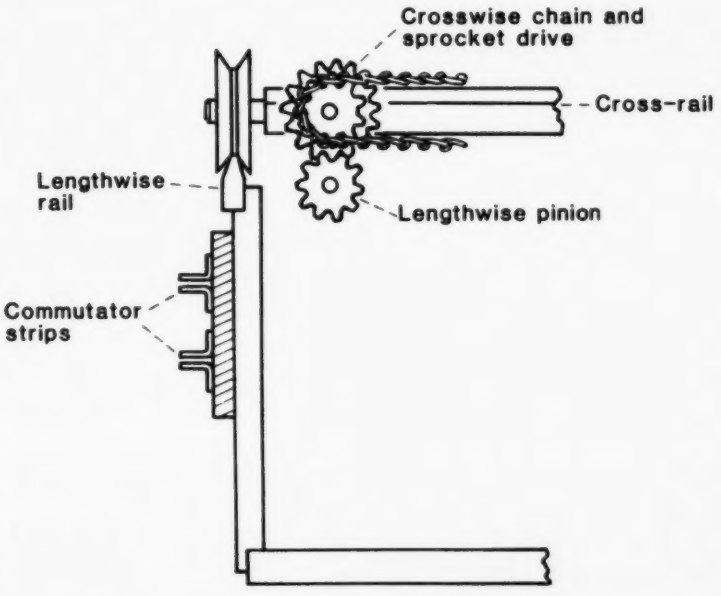

Fig. 15. One edge of the shelf assembly, and view.

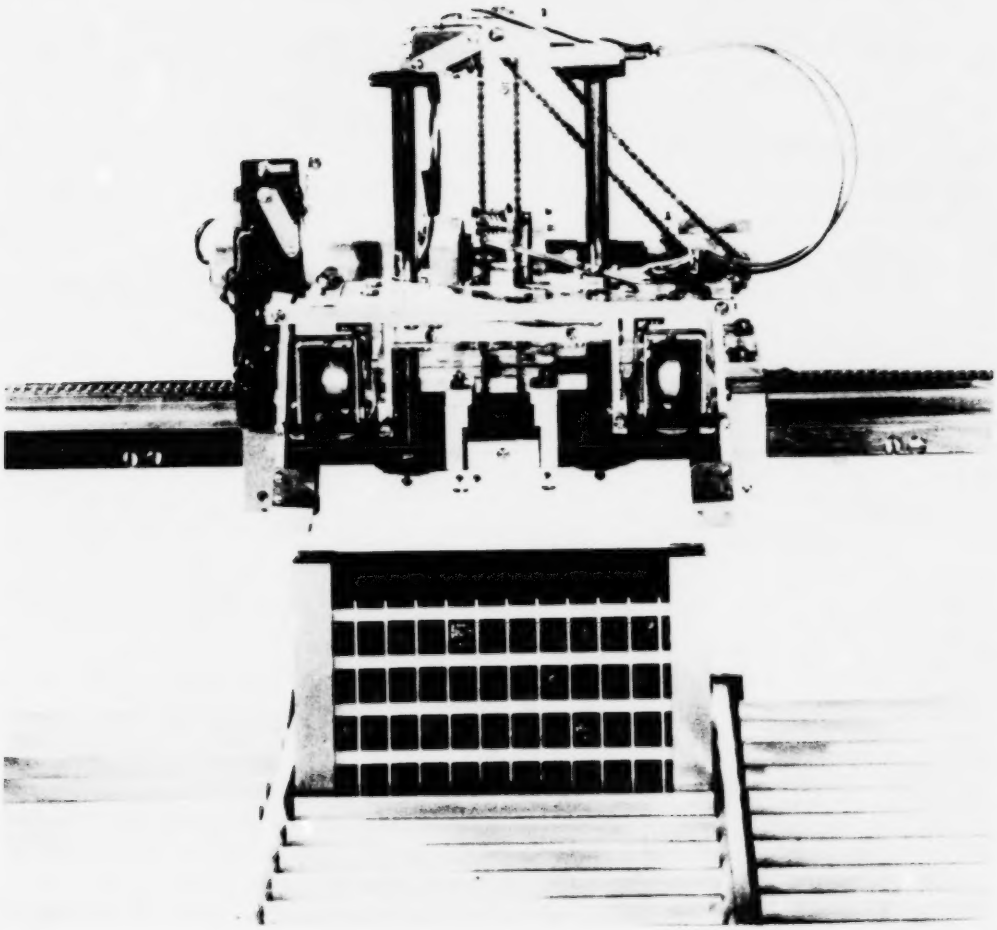

Figure 16. The tray pick-up unit.

pieces are the tray grippers, with a protrusion on each to match indentations on the ends of the trays. These pieces are held in the gripping position by springs and forced out by solenoids. Power is applied only for a short interval during pick-up and release of a tray.

The pick-up mechanism operates over the leading edge of the carriage so that the mechanism functions above and below the level of the cross-rails. Consequently, there is a considerable turning moment when the cross-rail assembly is under acceleration. The carriage is therefore held on to the rails from beneath as well, by rollers running along the underside of the rails.

Having picked up a tray, the object is to deliver it to the tray carriage on the viewing station. This carriage is 2 in. higher in level than the tray shelf, and consequently there are two operating levels for the pick-up mechanism. When picking up from, or delivering to, the tray shelf, it operates to its full travel; when the viewing station is involved, it operates to the shorter depth.

The Lengthwise Drive

The cross-rail assembly is driven the length of the unit (the X-motion) by chain and sprocket drives from a stepping motor. With the 3 ft span of this assembly, it is better to drive it from both ends, with the driving sprockets on each side coupled by a rigid shaft running the width of the unit. The chains run parallel to the side rails, about 2 in. inside the rails. With the proposed 8 ft span, it would probably be essential to drive the cross-rail assembly from both ends.

The X-positioning system to locate a required tray (0.9 in. centre-to-centre spacing) is a closed-loop servo system with photo-electric sensing, described in Appendix B. At present, a stepping motor provides the drive, but it is being used only for expediency as a variable speed, reversible motor. There are probably sufficient sensors in place to convert to a smoother, faster, dc servo-system.

Crosswise Drive for the Pick-up Carriage

There is a chain and sprocket drive on the cross rail assembly to drive the pick-up carriage across the width of the cross-rails (Y-motion). To keep the weight of this assembly to a minimum, the drive motor for this motion is mounted on the shelf, and the shaft motion is coupled to the chain and sprocket drive by a pinion gear running the length of the unit and just inside one of the side rails. Pinion gears sufficiently long (3 ft) were not readily available, and so two pieces are coupled by a gear arrangement as shown in Fig. 17. This method provides support to the pinion shaft as well, as would be required for the long shelves proposed.

There is a gear on the cross-rail assembly, also shown in Fig. 17, which constantly meshes with the pinion as the assembly travels lengthwise. This gear is wide enough to bridge the gap between the pinion shafts and is coupled to a sprocket which positions the carriage by a chain drive.

The cross-motion drive system must also incorporate a positioning system to locate the required tray in accordance with the address. This system is essentially a duplicate of the X-positioning system described in Appendix B. However, because of time-shared circuitry in the prototype, the X and Y motions cannot run simultaneously.

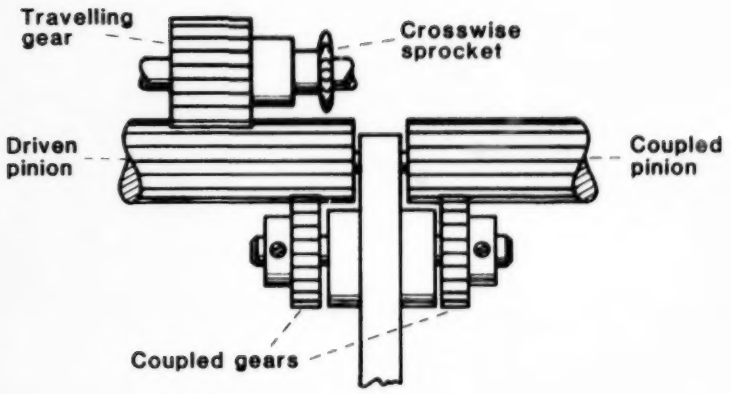

Figure 17. Pinion coupling and support.

The stepping motors used for these systems (Sigma type 21-342, 10 W) drive the pick-up assembly at a velocity of 8 in./s. This is much slower than would be required to meet the original specifications (10 s search and delivery time with a 30 ft × 8 ft shelf). With the same stepping motors the search time could be decreased by the methods previously described for the viewing stations (more sophisticated drive circuitry, simultaneous X and Y motion), but it is more likely that dc servo-systems would be incorporated.

Figure 18 shows the overall system to date, with the viewing station attached to the tray delivery system, and a frame from a fiche presented on a video monitor. The camera and monitor are 525 line broadcast standard equipment, and not a high resolution system as would eventually be required.

Tray Addressing

Trays are located by an X and Y address, and if more than one shelf were involved, there would be a Z address as well. For the demonstration model, tray X-addresses start from 1, rather than from 0, so that a 0 address can be used for the special case in which it is desirable to unload the viewing station, replace the tray, and to stop without re-loading another tray.

When a new request is entered, the old tray address must remain in a memory so that the tray can be returned to its proper location on the shelf. In case this address were lost due to power failure or circuit failure, it has been suggested that each tray be marked with a bar-code label indicating its shelf-address. Failing this, there should at least be a non-volatile memory to retain the addresses of trays that are out of

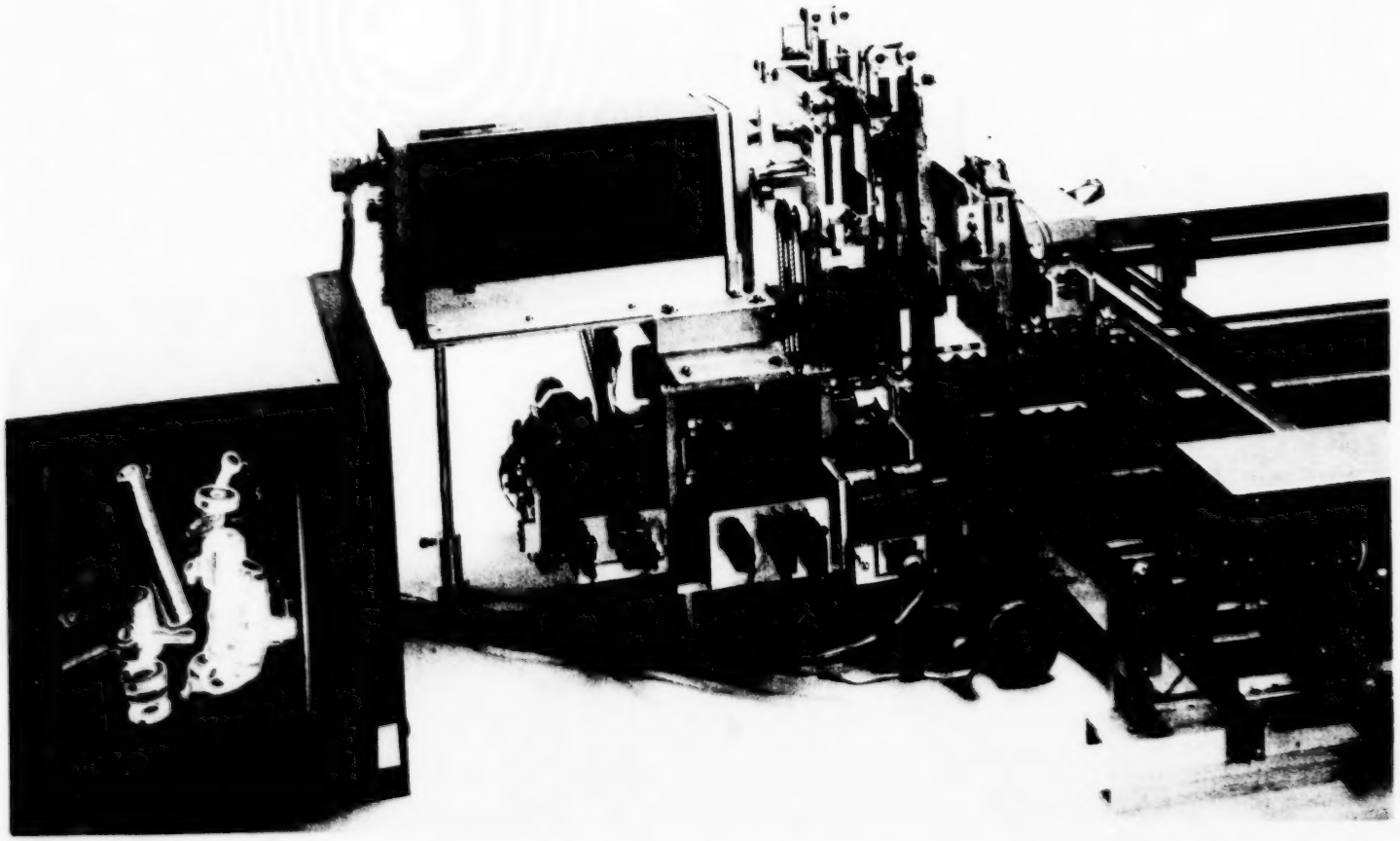

Figure 18. The viewing station and the tray storage unit combined.

position during an interruption of power. In this situation with the prototype, there is a simple initializing procedure to be followed to restore the tray address. Figure 19 illustrates the logic functions required to handle all situations following an address entry, i.e., tray change, fiche change or simple frame change.

Figure 19. Major steps following an address entry.

Shelf Height and Storage Density

The height of the tray storage unit, from the shelf to the top of the pick-up mechanism is 12 in. or about three times the height of a tray. The absolute minimum is twice the height of a tray, and a reasonable compromise to aim for in a re-design would be 10 in. When allowance is made for shelf thickness and a supporting structure, a minimum of 12 in. would be required with the fiche stored with their long dimension on the shelf. However, in the original proposal the fiche were to be stored on end (the reason for this is explained below), in which case 4 in. more would be required per shelf, i.e., twice the difference in the tray dimensions. Each shelf would then require 16 in., and six shelves would be 8 ft in height.

The storage density works out to be 200 fiche per square foot of shelf-space, whereas the storage density of the Anstin proposal is twice this number, or 400 fiche per square foot. Part of this difference is accounted for by the fact that the fiche spacing in the prototype trays is 0.060 in. compared to the proposed 0.050 in., and the tray separation on the shelf maybe greater than necessary. However, the major factor is that in the Anstin proposal, the fiche were to sit on end on the shelves, to achieve the greatest possible storage density for a given area. The height of the unit would increase about 4 in. for every shelf, but this is not as important as utilizing shelf area to the maximum. If the trays were sitting on end, the trays would have to be rotated through 90° at some stage. This rotation would be an added complication, and for expediency, it was decided to start with the simple pick-up system that has been described.

However, some thought has been given to such a tray rotation, and it would appear simplest to do after delivery to the tray carriage on the viewer. The open box which accepts the tray on the end of the tray carriage would be hinged at one corner to rotate through 90°. A possible system is described in Appendix E.

Rather than rotate the tray (and fiche), another possibility would be to maintain the fiche in a narrow-side-down orientation for the whole operation. The trays would have their opening on one of the narrower edges, and the fiche would be withdrawn by gripping a side edge. The only problem is that there is not always 1/8 in. of free space at the edge of a fiche for the grippers. Removing the grippers from the fiche in the viewing position would be an added complication.

PROBLEMS THAT STILL NEED CONSIDERATION

There are at least two problems involving hardware that have not been addressed. The first involves infiling, purging, and provision for fiche duplication. This problem is discussed in Appendix C.

A second problem is that of servicing storage shelves of the proposed dimensions. If, for example, a tray were not properly seated in the middle of an 8 ft × 30 ft shelf, and with a shelf above, how does an operator correct the situation? If the tray pick-up mechanism became stuck in the down position in the middle of a shelf, how do we move the carriage to one end of the shelf so that it can be serviced? These questions should be considered before large shelves are built and stacked one above the other.

CONCLUSION

Aside from the problem of infiling and fiche duplication, a microfiche storage and retrieval system can be built along the lines of the proposal by Anstin Automation Incorporated, but the viewing station is mechanically quite complex, and the system would not be inexpensive. One possible simplification would be to use rotary solenoids in place of the dc motor drive for the window separation, as discussed in Appendix A. Also, the prototype system fails in several ways to meet the specifications of the proposal, and further work would be required in these areas. For example, the size of the viewing station would not permit four units per shelf, and the storage density is about half that proposed. The delivery time at present, extended to a full-size shelf, would be much longer than the proposed 10 s maximum access time. A closer approach to this and to the specified storage density would not be too difficult. However, reducing the size of the viewing station the required amount might be difficult to achieve.

ACKNOWLEDGEMENTS

This work would not have been carried out without the overall concept submitted by Anstin Automation Incorporated, and this contribution is gratefully acknowledged. Mr. W.C. Brown, now retired and former head of the Information Science Section of the Electrical Engineering Division, NRC, was instrumental in obtaining the Anstin proposal, and thanks are due also to the current section head, Mr. J.W. Brahan, for his continued support of the project. Mr. François Alie assisted in the construction, and his skills, both electrical and mechanical, are greatly appreciated.

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APPENDIX A. THE WINDOW SEPARATION MECHANISM

Four rotating wedges are used to spread the window pieces approximately 1/4 in. A small dc motor drives the wedges using chain and sprocket drives from a gear-box and escapement mechanism, which is mounted on the back of the unit. The four wedges are driven in synchronism, and the three window conditions, namely closed, top open, open, are obtained by having three stopping positions for the output shafts of the gear-box, as shown in Fig. A-1.

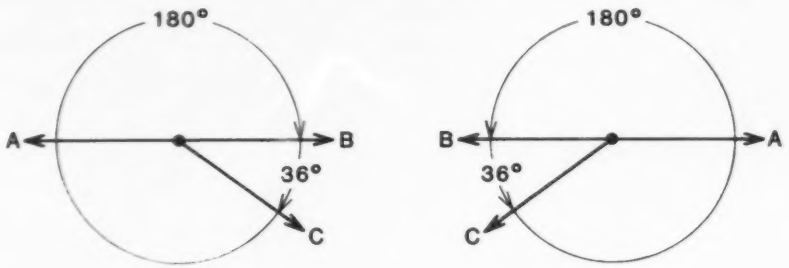

Figure A-1. Shaft positions for driving the window-spreaders.

In position A, the window is closed upon the fiche, and the arms are out of the way of the left-right movement of the window.

In position B, 180° from the initial position, the top of the window is open, but the bottom wedges are not yet engaged.

In position C, 36° farther, the top wedges are still engaged, holding the top open, and the bottom wedges are now engaged, opening the bottom as well.

With this arrangement, the requirements for the drive mechanism can be summarized as follows:

(1) two counter-rotating shafts, with each shaft uni-directional, i.e., no reversal is required

(2) shaft speed about 1 rps

(3) three stopping positions as shown in Fig. A-1

(4) two in.-lb. of torque (1 in.-lb per corner, two at a time)

The gear-box and escapement mechanism is quite complex, and the possibility of replacing it with four rotary solenoids was considered. The top two solenoids would be operated first to open the top of the window.

The maximum shaft motion available is 95°, and thus a 2:1 gear drive would be required to obtain 180° motion. The torque requirement would therefore be 2 in.-lb per unit while actually spreading the window pieces. After opening, however, the torque would only have to counteract the return spring, and the current could be reduced. Thus, a rotary solenoid with a continuous duty rating of only 0.2 in.-lb (95° motion) would probably be satisfactory. Such solenoids weigh 9 oz and four would be required.

APPENDIX B. LENGTHWISE SERVO DRIVE FOR A TRAY PICK-UP

This servo system drives the crosswise carriage assembly along the lengthwise rails of the storage shelf, a distance of 28 in. To pick up a tray, the carriage must be positioned within ±0.05 in. at intervals of 0.9 in. There are sensors to provide the following information:

(1) which tray location the carriage is nearest

(2) which direction the carriage must travel to reach the pick-up position, after it is in the vicinity of the requested tray

(3) the pick-up position

The sensors are light-sensitive diodes, 10 in all, mounted on one end of the crosswise carriage assembly. These sensors read a binary-coded film strip, with seven channels for the binary code (only five channels are needed at present), and three control channels as shown in Fig. B-1. The binary code changes half-way between pick-up positions, and to prevent a momentary false reading during a transition, the pulses on channel 10 inhibit a change in read-out near a transition. Channels 8 and 9 control the direction and the stopping point after equality has been reached between the requested address and the binary read-out. The inhibit signal (channel 10) is used only at the sending end and does not have to be transmitted to the control circuitry. The remaining bits are transmitted serially over a single commutator rail at a repetition rate of 280 times per second.

At present, these control signals are used to control a 10-W stepping motor, to drive the carriage assembly at a velocity of 8 in./s. The pulses to the stepping motor are generated by a voltage-controlled oscillator (VCO) so that acceleration and deceleration can be controlled. When the carriage assembly is one position away from its goal, the control voltage to the VCO is decreased relatively slowly (time constant approx. 1/10 s) to slow down the movement, and decrease the mechanical shock to the system upon stopping.

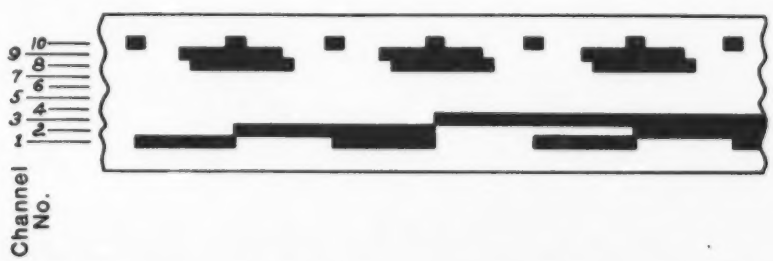

Figure B-1. A full scale segment of the binary coded film strip for servo positioning of the tray pick-up unit.

The crosswise drive is essentially the same, except for the anticipation for deceleration. With stopping points about 7 in. apart, it would be too early to start decelerating when the carriage is one position away from its goal. A separate channel on the film strip is used for this purpose, to indicate when the carriage is approximately 1 in. from its goal.

It is anticipated that these sensors could be used to control a smoother, faster, dc servo system. However, with the speeds required, it would probably be impossible to completely eliminate mechanical shock to the system on starting and stopping the carriage assembly. Consequently, if more than one camera were being used, the viewing stations would have to be mechanically isolated from the shelves to prevent vibration of a viewing station in use, while another is being loaded or unloaded.

APPENDIX C. INFILING, PURGING, AND MICROFICHE DUPLICATION

No attempt has been made to build a mechanism for infiling, purging, or temporary removal of a fiche for duplication (actual fiche duplication, not hard copy duplication). In the Anstin Proposal, the "Infile, Purge and Reproduction Bay" is at one end of the storage shelves, opposite to that of the viewing stations. For infiling, new microfiche would be inserted into a special infile tray serving all storage levels, and there would therefore have to be an "elevator" to bring fiche up and down from the input level. Similarly, fiche from all levels would be brought to a single level for duplicating on a diazo duplicator, and returned without an operator handling the fiche. The proposed system is designed to eliminate misfilings, but it would add a new dimension of complexity, explained as follows.

With the storage and viewing system constructed thus far, the fiche are always under control within the machine. They are either in a tray, or grasped by the grippers and sandwiched between two window pieces. To deliver a fiche to another machine, to release it, and to retrieve it again, is a problem of another dimension.

A simpler system, but more subject to misfiles, would be to have the tray in question delivered to a tray load/unload position on each storage level. As on the viewing stations, there would be a tray carriage to position the required fiche over push-up pins. For removal, the fiche in question would be pushed up sufficiently to be grasped by gloved fingers. For fiche insertion, guides would be activated to aid in manually inserting the fiche into the required slot. To prevent misfilings, the fiche selector mechanism could be permitted to function at only one level at a time. If a fiche were pushed up for removal at one level, the mechanism would not function at other levels until either the fiche was returned, or a purge function initiated to return the tray without that fiche.

This might help prevent misfiles, but it would not insure that fiche are inserted with the proper orientation. This might be overcome with sweep reversal switches on the monitor consoles, without having to inform an operator to re-orient a particular fiche. It should be noted, however, that even though the viewing system could tolerate incorrectly inserted fiche by means of sweep reversal switches, there would be a problem with the frame address. For example, if a fiche were inserted upside-down, the wrong row would be presented. This could be overcome by a simple arithmetic operation on the address, and this operation could be invoked automatically when a sweep reversal switch is actuated.

APPENDIX D. ADDRESSING BY PAGE NUMBER

After the required microfiche has been found and is being viewed, there are at present two methods of changing frames. A new row and/or column address can be given, or the one-frame-at-a-time controls can be used. For some requirements this might be sufficient. However, the sample microfiche used in this investigation are copies of scientific documents with numbered pages, and it becomes obvious that for this type of storage, addressing by page number would be a requirement. To do this, one would have to know the row/column address (or frame number) of some specific page, and the row/column address of any other page could then easily be computed, knowing the format of the fiche in question.

The problem is that the frame number for a specific page varies because of the variable number of un-numbered pages at the beginning of a document. A reference is needed, and two ways have been considered to provide this. For one method, the operator would first have to be viewing a numbered page of the document. The operator would then enter this page number on the keyboard at the viewing console, followed by (or preceded by) a suitable command. This page number would then be associated in temporary memory with the row/column address of the frame being viewed. The operator would then enter the required page number together with a suitable command; the row/column address of the page would be computed, and the frame presented. If there were un-numbered pages between the reference page and the required page, there would be an error. Small errors could be corrected by the next-frame function, while for large errors the procedure could be repeated to "zero-in" on the required page.

In the second method, when the fiche is filed, an additional parameter would be added to the file number. This parameter would indicate the number of frames on the fiche before numbered pages begin. With this information, the row/column address of any page could be found, provided all pages are numbered.

A combination of the two methods might be best, to minimize the effort on the part of the operator for what is probably the majority situation (all pages numbered), and still permit corrections to be made if there are un-numbered pages. The procedure could be extended to handle the case of documents requiring more than one microfiche.

APPENDIX E. ROTATING THE TRAYS THROUGH 90°

To maximize the number of trays that can be stored in a given area, the trays, should be stored upright on one of their side edges. If this were the case, a 90° rotation of the tray would be required at some stage. To investigate how this might be achieved, a mock-up was made of the bottom-front portion of the viewing station, including the extended tray carriage.

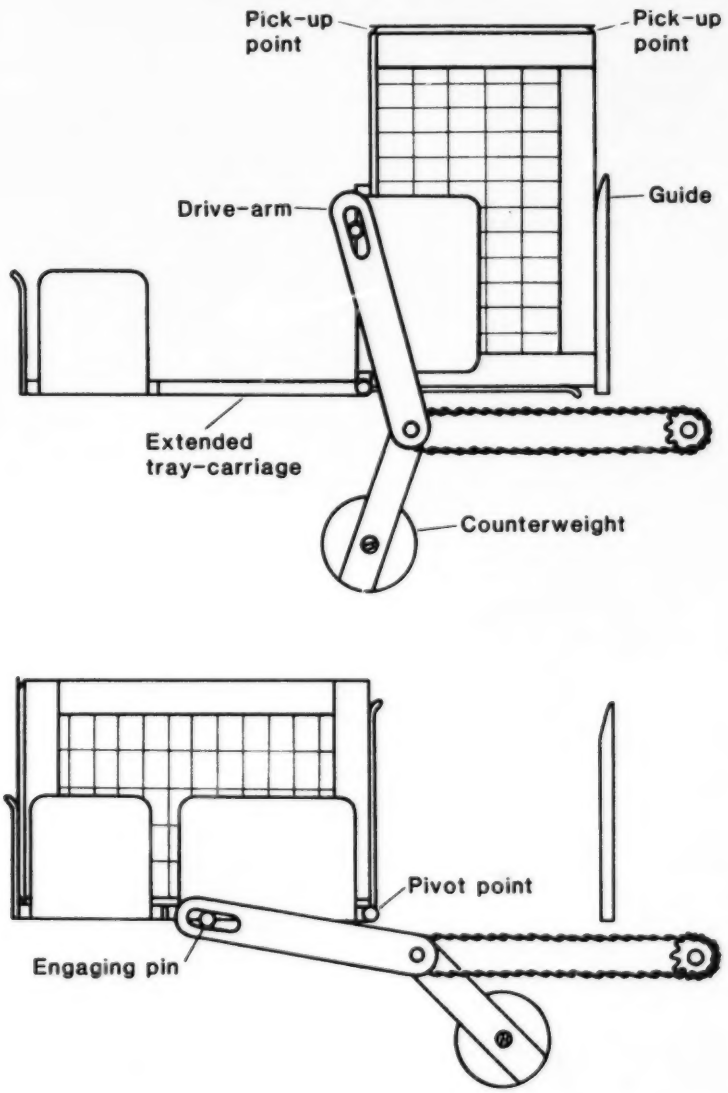

Figure E-1. Tray rotation mechanism. The top figure shows the tray load/unload position. The bottom figure shows the position for moving the tray into the viewing station.

As shown in Fig. E-1, the open box on the end of the tray carriage is divided into two parts. The smaller section is fixed to the tray carriage, while the larger section is free to pivot about an axle fastened to an outer edge of the tray carriage.

For motive power there is a motor-driven arm with its centre of rotation as close as practical to the centre of rotation of the pivotting section of the box. When the tray carriage is in its extended position, a projection on this section of the box engages a slot in the motor driven arm, so that the box can be rotated. The arm is driven through a chain and sprocket drive from a small dc motor with internal reduction gears. With the chain and sprocket drive and an extended shaft, the motor can be mounted to the side and rear of the viewing station, so that it does not interfere with the sideways motion of the right-left carriage, or with the mating of the viewing station to the tray storage unit.

Some modifications are needed to the tray pick-up system as well. For the original system, there are notches in the side pieces of the trays (see Figs. 1 and 2) for the grippers to engage. However, it is not as easy to do this on the top and bottom of the tray as would now be required. As a possible solution, a tray was modified as shown in Fig. E-1. A piece of 1/8 in. aluminum, capped by a piece of thin steel, is fastened to one edge of the tray to provide pick-up points on the upper corners as indicated.